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AN INVESTIGATION INTO A RELATIONSHIP BETWEEN UPPER-AIR RELATIVE HUMIDITY AND CLOUD COVER

BY

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Introduction

The filtering effect of the atmosphere upon radiation is increased by the presence of cloud. Cloud absorbs or reflects radiation according to type and thickness and the greatest differences are between low, medium and high cloud groups. The greatest single factor in cloud formation is relative humidity, which can be forecast numerically.

Designed in the context of the ten-level numerical model, this work was intended to improve on the relationships given by Gadd and Keers[2]. They had compared 12-hour forecasts of humidity values at the grid-points of the 48 x 32 point rectangular (fine mesh) area with the observed cloud distribution taken from synoptic charts. Earlier work by Smagorinsky[1] was based on comparisons between observed humidities and cloud cover values. The relationships obtained by Gadd and Keers were fairly similar to Smagorinsky's for medium and high cloud, but somewhat different for low cloud. Both defined low cloud as in the 1000 - 800 mb range but there was a slight difference between their respective definitions of the ranges for medium and high cloud.

Initially, it was intended to do the comparisons with each parameter (humidity and cloud cover) smoothed over grid squares, but no attempt to discriminate between cloud levels could reasonably be made on this basis. Comparisons between total cloud cover and the highest humidity value over a 100 mb layer were, however, made in the grid square context, on the assumption that the predominant cloud would be in the wettest layer.

Later, in a further analysis, low, medium and high clouds were considered separately and compared with humidity in the 1000 - 800, 800 - 500, 500 - 300 mb ranges respectively. Relative humidities were averaged vertically over 100 mb

layers from the surface to 300 mb. The amount of cloud in each range was compared with humidity in two ways -

a. the highest averaged humidity value; and

b. the mean humidity over the entire range.

These were known as type A and type B comparisons respectively. Such an analysis could not be made over grid square areas, so reported cloud amount was compared with observations of relative humidity taken at approximately the same time.

Date collection and analysis

Periods of a fortnight considered to be representative of each of the four seasons were chosen for the investigation. These were:

16 - 31 January 1969

16 - 30 April 1969

16 - 31 July 1969

16 - 31 October 1969

The amount of data that could be used was limited by the fact that radiosonde observations, in general, are taken only twice daily: at noon and midnight. Only stations in the UK were considered - Lerwick, Stornoway, Shanwell, Long Kesh, Aughton, Hemsby, Crawley and Camborne, with the addition of the supplementary stations Aberporth, Shoeburyness, Larkhill and Eskmeals - and humidity data were taken for midnight and midday.

It was originally intended to calculate the mean relative humidities over 100 mb layers from the 1000, 900, 800, ... mb values by calculating a simple arithmetic mean of each pair of level values. This was found to give incorrect results in some instances when compared with the tephigrams. Vaisala diagrams, which contain plottings of relative humidity measured in an ascent, were used, the mean humidities over the 100 mb layers being assessed by eye and tabulated for each of the above stations for the times stated.

Particular care had to be taken to check the time of ascent, because of the comparison with standard time surface observations of cloud cover. The noon ascent takes place nominally at 1115 GMT and the midnight ascent at 2315 GMT, but there were occasional late starts, and the supplementary stations often made soundings at other times. Only those ascents made within 2 hours either side of noon and midnight were considered. Where two succeeding soundings fell in this category, that made nearer the appropriate time was used.

As the layer humidities had had to be interpolated over grid squares, a precision to the nearest 1 per cent was unjustified. The grid squares were therefore categorised in humidity ranges as follows:

A	greater than	90%
B		80 - 90%
C		70 - 80%
D		60 - 70%
E	less than	60%

Cloud cover categorisations were as follows:

b	less than $\frac{1}{4}$ cover
bc	between $\frac{1}{4}$ and $\frac{3}{4}$ cover
c	greater than $\frac{3}{4}$ cover

Only those grid squares which lay wholly or very largely over land in the UK were considered, and small overprinted charts were available for plotting (see fig 1).

Cloud cover interpolations were made by using a transparent overlay on hourly charts and deducing each grid square category from the plotted observations. These were supplemented by Essa 8 cloud photographs [3] for daytime observations only.

When the relative humidity and total cloud cover interpolations had each been plotted, they were compared, and tables of these comparisons at noon and midnight for each season were drawn up. In spite of the inaccuracies in interpolating over

grid square areas - particularly humidity data, which are sparse and distributed mainly in coastal regions - it was evident that there is an association between the two variables. Its most striking feature was that small cloud cover seemed to be associated with higher relative humidities than has been previously indicated (1), (2).

00Z WINTER

	E	D	C	B	A
c	0	0	38	146	5
bc	0	2	33	29	0
b	0	2	21	12	0

(a) 288

12Z WINTER

	E	D	C	B	A
c	0	3	77	140	7
bc	0	1	43	10	1
b	0	2	4	1	0

(b) 288

SPRING

	E	D	C	B	A
c	0	2	31	79	1
bc	1	12	48	18	0
b	2	26	44	6	0

(c) 270

SPRING

	E	D	C	B	A
c	1	10	105	75	4
	2	22	33	15	2
	0	1	0	0	0

(d) 270

SUMMER

	E	D	C	B	A
c	0	6	24	79	13
bc	0	9	59	37	0
b	0	11	36	14	0

(e) 288

SUMMER

	E	D	C	B	A
c	0	5	70	91	13
bc	1	34	49	5	0
b	0	8	12	0	0

(f) 288

AUTUMN

	E	D	C	B	A
c	2	4	18	124	4
bc	0	17	42	39	2
b	5	6	19	6	0

(g) 288

AUTUMN

	E	D	C	B	A
c	1	8	78	106	12
	2	20	29	14	1
	3	11	3	0	0

(h) 288

TABLE 1

The seasonal differences in the comparisons given in Table 1 (a-h) do not appear to be very consistent, but there is a consistent diurnal difference. There are far fewer "b" categorisations and fewer "bc" categorisations by day than by night. As may be seen in Table 2(a) and (b), the corresponding increase in "c" categorisations is almost entirely in the 70 - 80% humidity range.

00Z

	E	D	C	D	A
c	<1	1	10	38	2
bc	<1	4	16	11	<1
b	1	4	11	3	0

(a)

12Z

	E	D	C	B	A
c	<1	2	29	36	3
bc	<1	7	13	4	<1
b	<1	2	2	<1	0

(b)

ALL CASES

	E	D	C	B	A
c	<1	2	19	37	3
bc	<1	5	15	7	<1
b	<1	3	6	2	0

(c)

TABLE 2

Totals expressed as percentages

Table 2(c) indicates a roughly linear relationship with extremities at about 70% and 85% relative humidity.

It was felt that the available 12, 24 and 36-hour numerical forecasts of layer humidities for the period 16- 22 January 1969 should be compared with the actuals. However, all but a few of the "wettest" layers in the forecasts were in the "A" category; so a detailed comparison was not carried out.

Further analysis

Although no discrimination between low, medium and high cloud had been attempted so far, some discrimination was clearly desirable. As was mentioned in the Introduction, this could only be done in terms of individual stations, and in

the first instance, three were used: Crawley, Shanwell and Long Kesh. The corresponding surface stations from which cloud reports were taken by means of DWRs were Gatwick, Leuchars and Aldergrove respectively. These stations were chosen for their position and for the fact that the surface stations were airfields, from which good cloud reports might be expected. The same periods and times were used as before.

Comparisons between cloud cover and relative humidity were as mentioned in the Introduction: type A, defining comparison of cloud cover with the humidity of the dampest of the hundred-millibar layers, and type B which defines the comparison of cloud cover with mean layer humidity. Each type defined low and medium cloud comparisons. No useful comparisons could be made for high cloud since the data were inadequate.

TYPE A

LOW CLOUD

cloud cover (oktas)	<20	20/30	30/40	40/50	50/60	60/70	70/80	80/90	>90
7, 8						4	31	103	22
5, 6							24	30	3
3, 4					1	4	24	16	1
≤ 2					8	28	62	15	2

RH(%) ↑

TYPE B

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LOW CLOUD

cloud cover (oktas)	<20	20/30	30/40	40/50	50/60	60/70	70/80	80/90	>90
7, 8				1	1	15	52	73	9
5, 6					2	10	31	19	2
3, 4					2	10	27	8	1
≤ 2			1	6	26	32	40	9	1

RH(%) ↑

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TYPE A

MEDIUM CLOUD

cloud cover (oktas)	<20	20/30	30/40	40/50	50/60	60/70	70/80	80/90	≥90
7, 8					2	5	15	10	1
5, 6			2	4		2	5	3	
3, 4					2	2	2		1
≤2	13	12	20	26	31	27	21	2	1

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RH (%) ↑ cloud cover (oktas)

TYPE B

MEDIUM CLOUD

cloud cover (oktas)	<20	20/30	30/40	40/50	50/60	60/70	70/80	80/90	>90
7, 8			2	1	3	11	15	3	
5, 6		3	1	3	2	1	5		
3, 4			1		3	1	1	1	
≤ 2	17	29	34	36	26	10	5		

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RH (%) ↑ cloud cover (oktas)

TABLE 3

Showing the distribution of the cloud cover - humidity comparisons

Unfortunately, the medium cloud distributions are unavoidably biassed. No estimates of medium cloud amount can be obtained when low cloud cover is greater than 6 oktas; and even when low cloud is moderately extensive, they can be badly in error.

More data was necessary before the regression lines corresponding to the distributions could be properly defined. The data used were for the same dates and times as before, and from upper air stations with surface stations nearby; Lerwick, Stornoway, Shanwell (Leuchars), Long Kesh (Aldergrove), Hemsby (Gorleston), Aberporth, Crawley (Gatwick) were the stations considered, surface station given in brackets where its name was different from upper-air station. Only those reports of medium cloud which was associated with 3 oktas or less of low cloud were used, except where medium cloud amount was greater than 6 oktas.

This time, the data were not grouped. From the scatter diagrams, Fig 2 (a-d), the type A analyses appear to show a more compact distribution than type B.

TABLE 4

	No. of obs.	Correlation coefficient	S.D. cloud cover	S.D. rel. humidity
Low cloud, type A analysis	788	0.57	2.47	6.77
" " type B "	788	0.54	2.54	8.74
Medium " " A "	293	0.59	2.58	15.92
" " " B "	293	0.63	2.48	14.99
" " " A " (ignoring points <50% R.H.)	192	0.59	2.69	8.76
" " " B " (ignoring points <50% R.H.)	128	0.60	2.66	7.70

N.B. type A analysis = cloud cover against highest humidity in 100 mb layers

type B analysis = cloud cover against mean humidity in low and medium cloud layers.

It is obvious from Table 4 that there is little real difference between type A and B analyses. The correlation coefficients for the medium cloud analyses are higher than for the low cloud because of the greater comparative concentration of points at the top and bottom ends of the cloud cover scale. Taking relative humidity to be on the X - axis and cloud cover on the Y - axis, regression lines were calculated and are as follows:-

	Low cloud		Medium cloud	
	type A	type B	type A	type B
X upon Y	X = 71.63+1.55Y	X = 65.31+1.85Y	X = 46.98+3.65Y	X = 36.48+3.83Y
Y upon X	Y = -11.54+0.21X	Y = -6.68+0.16X	Y = -2.79+0.10X	Y = -2.23+0.10X
X upon Y (ignoring points < 50% R.H.)	X = 54.11+5.15Y		X = 51.11+4.86Y	
Y upon X (ignoring points < 50% R.H.)	Y = -10.45+0.19X		Y = -10.09+0.20X	

To predict cloud cover from humidity, the Y upon X line is used.

Owing to the concentration at the bottom end of the scale, the regression lines for medium cloud predicted less than 8 oktas cloud cover at 100% relative humidity, which is clearly physically unreasonable. It was therefore desirable to reduce the biassing or weighting effect of these points.

The difference between the parameters for type A and B analyses given in Table 4 were tested for significance at the 5% level. Only the humidity standard

deviations for the low cloud analyses were significantly different, confirming the visual impression of the greater scatter of type B. For this reason, it was decided to accept the regression lines calculated from the type A analyses, provided they were physically reasonable.

In order to improve the medium cloud line, the distributions were analysed as shown in Fig 3. It is immediately noticeable, particularly with medium cloud, that points below about 50% R.H. are differently distributed to those above. Since, on the average, they are of 1 or 2 oktas cloud amount, they would have little effect on radiation and may for all practical purposes be ignored. The regression lines for low and medium cloud were recalculated on this basis and, to the nearest 5% R.H., are shown in Fig 3.

Conclusions

The analysis over grid squares indicates that clear skies can be associated with much higher mean humidities than appears to be shown by Smagorinsky or Gadd and Keers. It was intended that the relationship between cloud cover and humidity should be determined on the grid square basis, whereas in practice, it was determined largely from the further analyses based on the individual station reports. The grid square analysis, which compared total cloud cover with the highest 100 mb humidity, is in many cases equivalent to a low cloud type A analysis. This is borne out by comparing Table 2(c) and Table 3. Hence, it was thought reasonable to determine the lines from the further analyses, since greater accuracy could be obtained in this way. It is interesting to note that both Smagorinsky and Gadd and Keers based their humdity classifications on a type B analysis, which gives a more spread out distribution than the type A, noticeably for low cloud.

With the exception of Crawley and Larkhill, UK radiosonde stations are situated on or near coasts. Lerwick particularly is representative of a purely maritime station whereas airstreams affecting other stations could be either maritime or continental in character. However, there was no evidence to suggest any significantly different distribution for any one station as against the others.

On the other hand, an area with a high proportion of convective activity, such as the sub tropics, may be expected to yield different results from the British Isles, where stratiform clouds tend to predominate. Any such difference should have been apparent between the distributions for each season (eg summer is a more convective time of year in the British Isles than winter), but seasonal differences were inconsistent, showing no evidence that there was any one predominant factor.

The lines proposed for the determination of low and medium cloud cover from relative humidity are given in Fig 3. A line was interpolated for high cloud, for the purposes of the 10-level model, by considering it to be similarly separated from the medium cloud line as that was from the low cloud line.

References

1. SMAGORINSKY J — 1960 — On the dynamical prediction of large scale condensation by numerical methods. WASH NAOS, Nat Res Council, Amer Geophys Union, Geophys Mon No 5 pp 71-78.

2. GADD A J and KEERS J F — 1970 — Surface exchanges of sensible and latent heat in a 10-level model atmosphere. Quart Journ Roy Met Soc Vol 96 p 301 Fig 2.

3. INST. FUR MET. UND GEOPHYSIK DER F. U. BERLIN — Essa 8 mosaics for the year 1969.

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FIG 1

Met.O/Carto/D.O./1535

MAX RELATIVE HUMIDITY OVER 100MB LAYER COMPARED WITH CLOUD AMOUNT

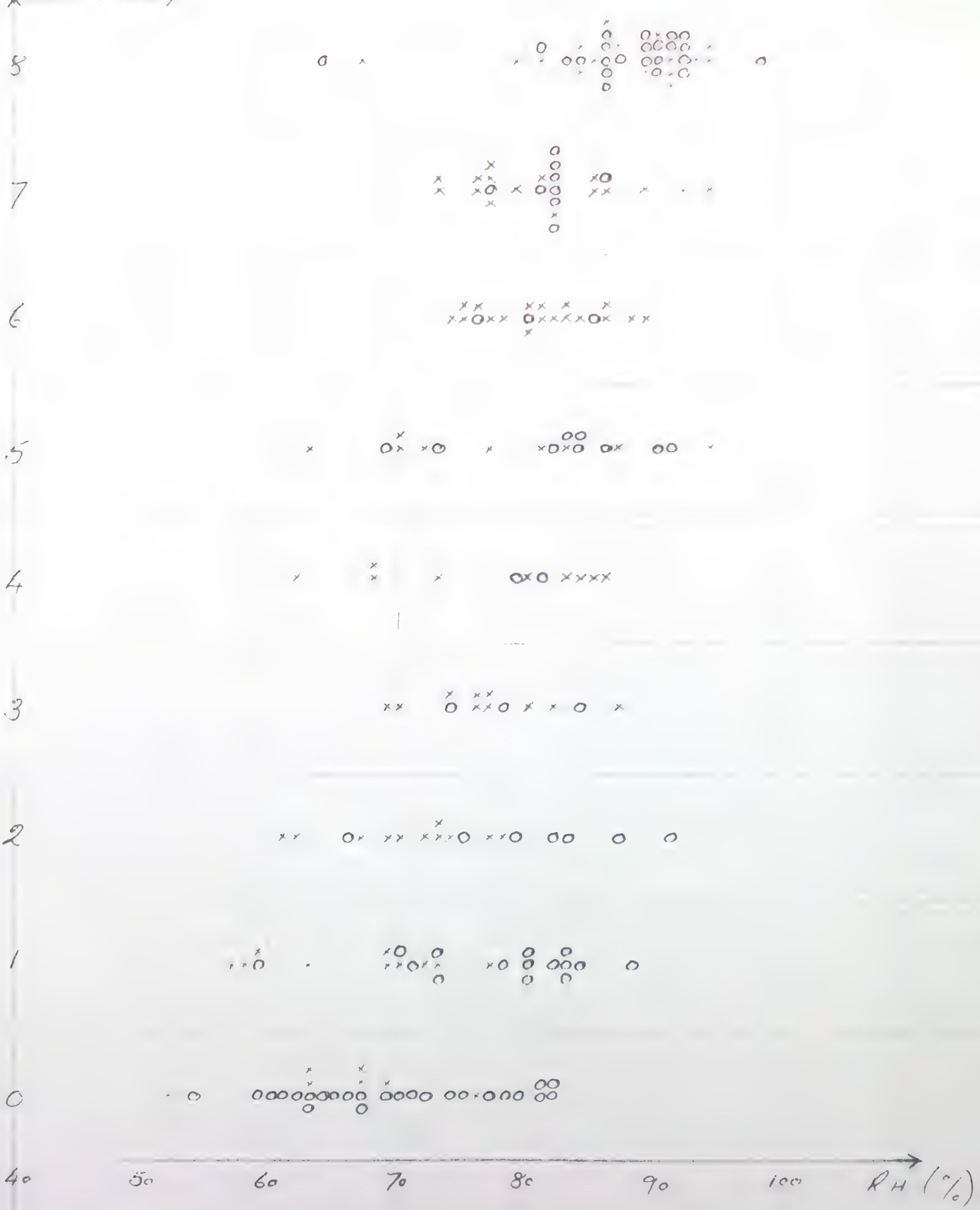
20th APRIL 1969 00

LOW CLOUD (TYPE A ANALYSIS)

SUMMER JULY 16th - 31st 1969

FIG 2(a)

o Night time ob.



LOW CLOUD (TYPE B ANALYSIS)

SUMMER JULY 16th -31st 1969

FIG 2(b)

o Nighttime ob

× Daytime ob

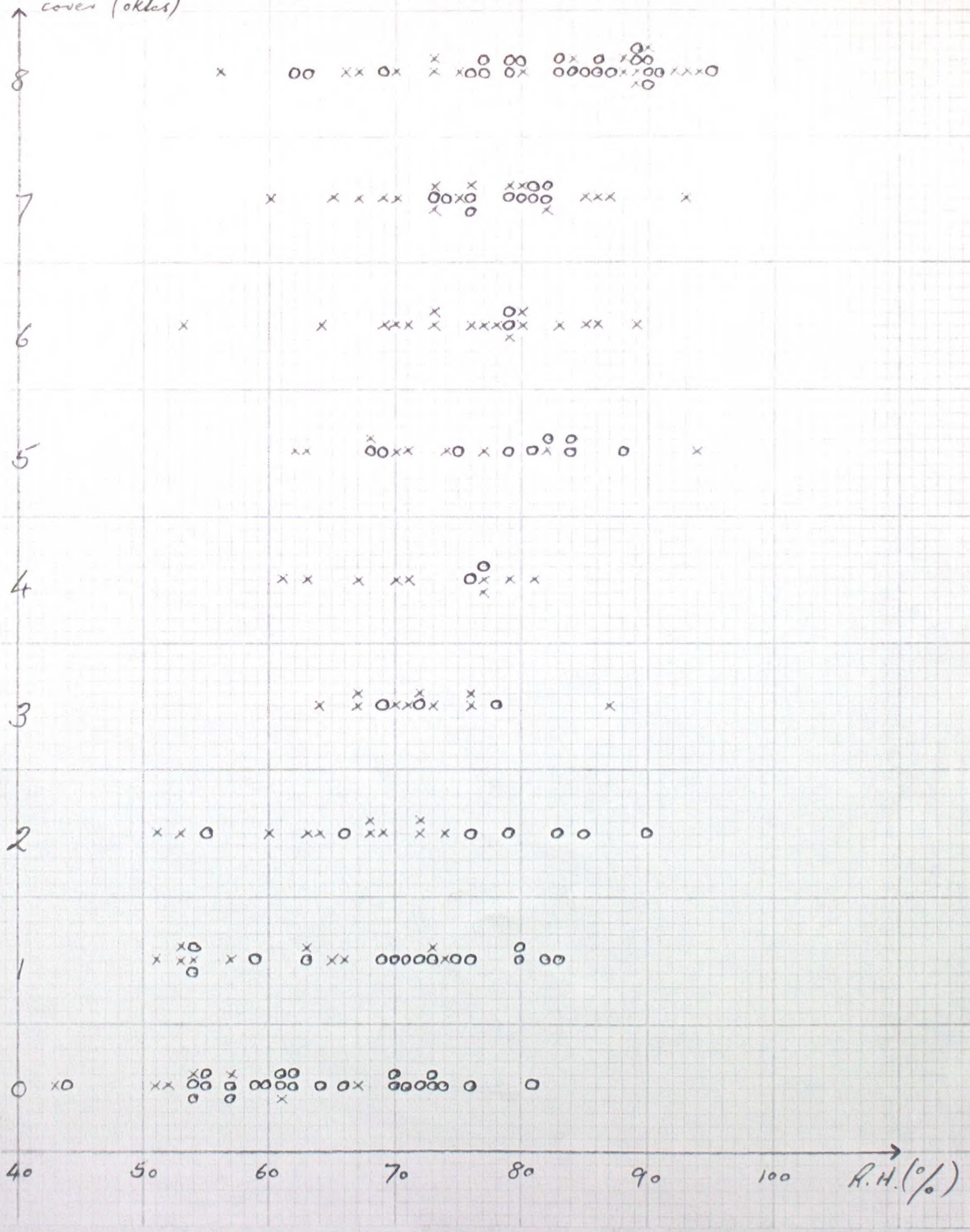


FIG 2 (c) MEDIUM CLOUD (TYPE A ANALYSIS)
from the stations given in the text.

00Z 16-31 January
12Z 16-30 April 1969.
16-31 July
16-31 October

⊙ Night time ob.
× Daytime ob.

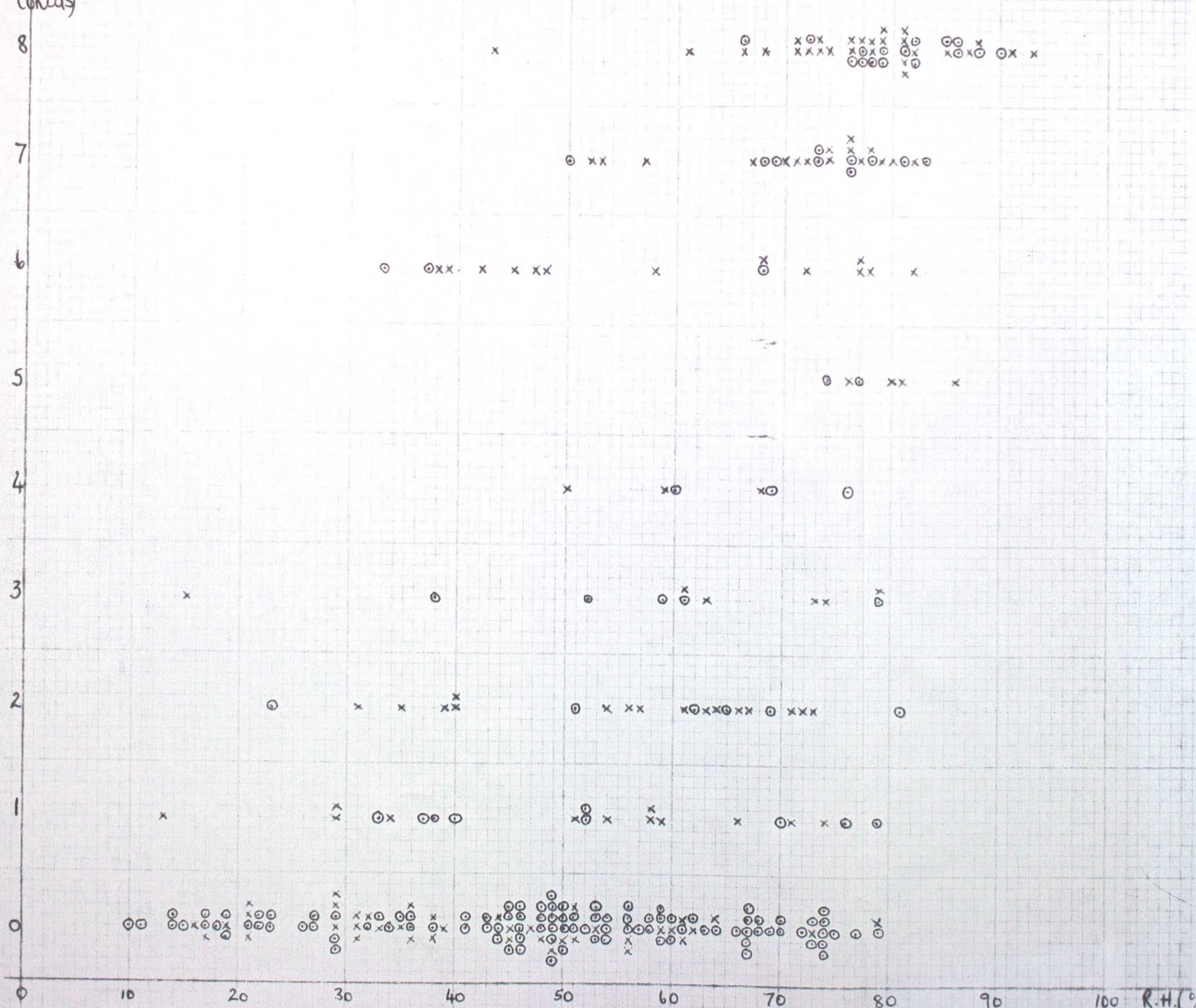


FIG 2 (d).

MEDIUM CLOUD (TYPE B ANALYSIS)
from the stations given in the text.

00Z 12Z
16-31 January
16-30 April
16-31 July
16-31 October
1969.

⊙ Night time ob.
× Daytime ob.

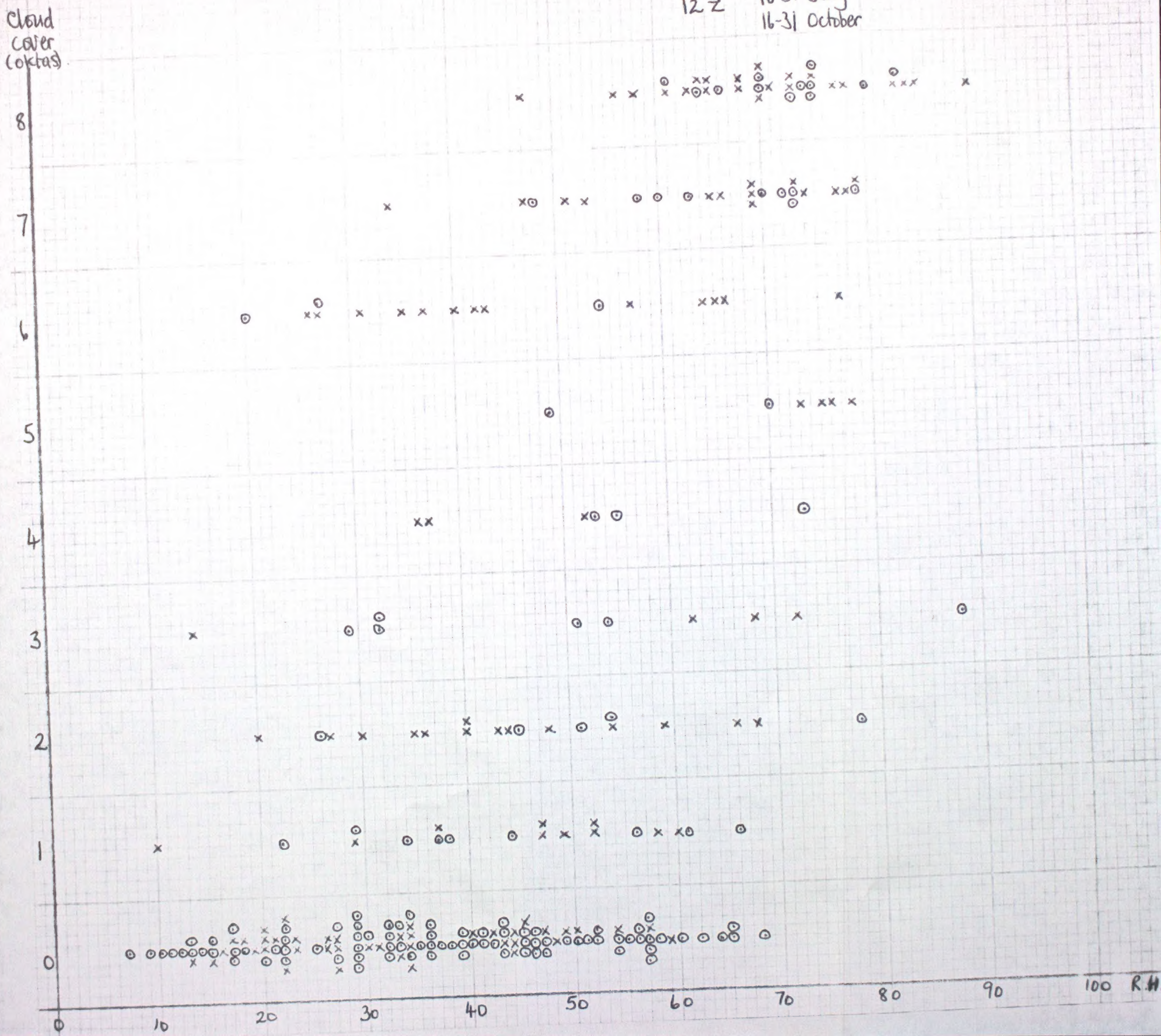
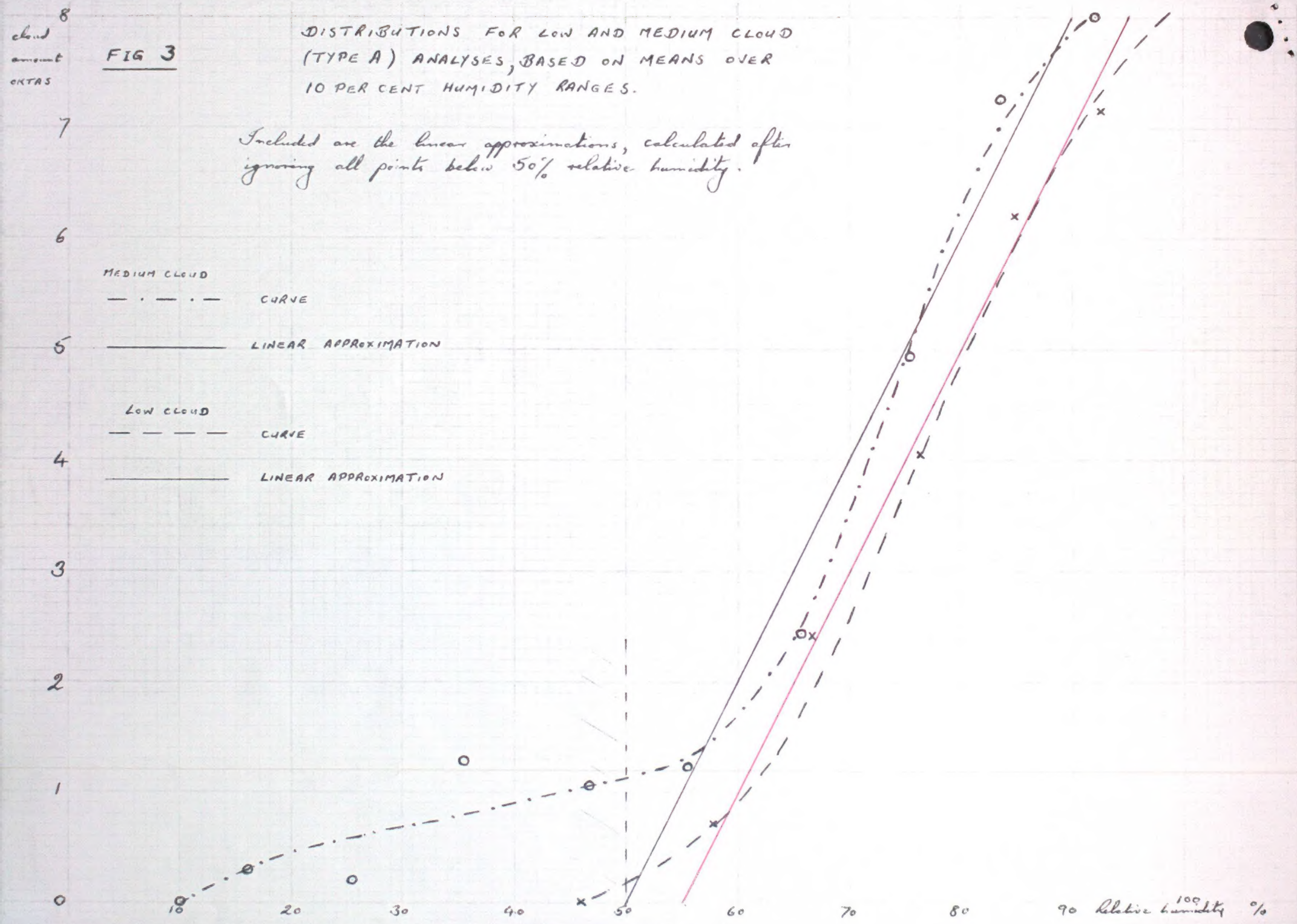


FIG 3

DISTRIBUTIONS FOR LOW AND MEDIUM CLOUD (TYPE A) ANALYSES, BASED ON MEANS OVER 10 PER CENT HUMIDITY RANGES.

Included are the linear approximations, calculated after ignoring all points below 50% relative humidity.